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Some Basic Problems in the Study of Geosynclines

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This article by A. V. Peyve and V. M. Sinitsyn is offered to the readers and is published for purposes of discussion, since the new concepts set forth by the authors on the evolution of the earth's crust, on magmatic processes, and on the processes of mineral formation are extremely debatable. (The Editors.)

Based on many years of personal investigations in a number of regions of Central and Middle Asia, Kazakhstan, the Urals and in the Caucasus, the authors offer new concepts on the origin, evolution and structure of geosynclines and platforms.

As a result of pre-upper Proterozoic development, the authors propose that a single metamorphic covering of continents (the "panplatform") was formed for future geosynclines and platforms. The geosyncline stage in the development of the earth's structure began in the beginning of the upper Proterozoic after a rapid acceleration in the evolution of all geologic processes. This stage is divided into several qualitatively different phases. The general characterization of the stages of geosyncline development forms the basic content of the present article.

1. INTRODUCTION

Soviet geologists must occupy the leading position in all fields of geological knowledge, and first and foremost, in geotectonics, which explains the general mechanisms of geological processes. We have everything necessary to accomplish this:

a spacious, diversely constructed territory, a great range of research, and a mighty Marxist - Leninist - Stalinist theory of knowledge.

The successes of Soviet scientists in geotectonics are great, but not all the problems of this science have been satisfactorily explained in the light of facts now at our disposal. The influence of foreign formalist theories has not been completely eradicated. This refers primarily to the most important part of contemporary geotectonics - studies on platforms and geosynclines. Soviet scientists should give this study the kind of support that will more effectively assist in solving practical and scientific problems.

It is obvious that when prospecting and searching for new oil and iron ore regions, for new deposits of non-ferrous and rare metals, for non-metallic materials and water resources, the correct theory of the origin and development of the basic structural elements of the earth's crust - of geosynclines and platforms - must in general be a guide by clarifying the mechanisms of the distribution of mineral resources. And this theory may be considered correct only in so far as it, on the one hand, satisfies practical demands, and on the other hand stimulates further scientific research particularly on ore locations, petrography, geophysics, geomorphology, historical geology, and many other studies, which are concerned with the basic problems arising out of geotectonics.

T. clarify the history of the development and changes in the structure of the earth's crust from the Archean period to the present time, it is necessary to clarify both quantitative and qualitative changes during the chief geological processes - folding, sediment accumulation, metamorphism, magmatism, metallogeny, etc. Furthermore, the differences and similarities of phenomena must be determined not on the basis of any one single feature, such as folding, but on the whole complex of the characteristics just enumerated. This permits us to distinguish several linked geological phases of the development of mobile belts in the earth which are characterized by special formations of rocks, special folding, magmatism, metamorphism, metallogeny, etc.

On the basis of one or two features (such as folding or the degree of mobility) it is impossible to isolate the stages and phases of structural evolution. However, a more detailed isolation of the various stages and phases of structural development may cause us to alter or even discard altogether some of the general concepts now found in our knowledge of geosynclines, and this makes the problem more complicated. With such a study, numerous questions immediately arise: is it correct to consider the Urals, Kazakhstan, Tyan'-Shan'* and other folded regions in the geosyncline type of Archean-lower-Proterozoic development? Is it practical to use this generalization, according to which the contemporary structure formation in the Asiatic mountain belt is considered as geosynclinal when, at the same time, the development of the territory of this belt is considered geosynclinal in the pre-Cambrian and Paleozoic periods? Should the zones of Caledonian, Hercynian and Alpine folding be considered platforms? Is the theory of the consecutive expansion of platforms and the progressive stabilization of the earth's crust correct? What stages and phases of the evolution of the earth's structure can be distinguished on the basis of geological phenomena such as: structure formation, sediment accumulation,

* [Tien-shan.]

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metamorphism and metallogeny?

As a result of our many years of research in geosyncline regions of Middle and Central Asia, Kazakhstan, the Urals and the Caucasus, we are convinced that certain basic propositions in the study of geosynclines do not meet contemporary requirements and are in need of review.

The conclusions we arrived at in the course of our work are new and are in conflict with certain concepts widely disseminated in scientific literature.

2. SOME OBSERVATIONS ON PRE-GEOSYNCLINE DEVELOPMENT OF THE EARTH'S STRUCTURE

All geologists unanimously agree that in the Archean and Proterozoic up to the beginning of the upper Proterozoic there were no large massifs of platforms on modern continents similar to the Russian or Siberian platforms. In pre-upper time it is assumed that the earth's crust "worked," according to an expression of V. V. Belousov, like a continuous pangeosyncline, separate parts of which then became locked in the succeeding geological periods, turning into stable platform zones.

The first large platforms appeared by the beginning of the upper-Proterozoic. Further development of the earth's crust consists, it is supposed, in the consecutive expansion of platform areas and of the end of geosynclines, which became filled up by folding systems developing like young platforms. The development of large geosyncline regions ends by their turning into platforms, but as N. S. Shatskiy, N. M. Strakhov and others, point out, we do not know the beginning of the formation of geosyncline systems and regions. We can determine that a given geosyncline system of region became locked in the Caledonian, Hercynian or Mesozoic periods, but we have never successfully explained when the development began.

In order to confirm or deny this, we must examine certain additional facts and considerations.

The theory of consecutive expansion of platforms from geosynclines which have ended, as S. Bubnov (the supporter of this theory) has very clearly observed is completely logical only if it is supposed that under geosynclines there are no significant old folded sialic foundations and that a geosyncline may attain a base of continental socle located almost immediately on the sialic floor. It must be said that Soviet geologists did not consider this circumstance and did not acknowledge it although at first they accepted the idea of the consecutive expansion of platforms propounded by E. Og. At the same time if the pre-upper Proterozoic sialic socle under later geosyncline formations should appear continous and similar in all its geological features to the sialic socle under the platforms, then we can naturally draw a conclusion concerning a single sialic covering over all continents which would be common for geosynclines and platforms alike.

Turning to any of the geosyncline regions - Alpine, Hercynian or Caledonian - we can see the pre-upper Proterozoic crystalline foundation coming out in most places and overlarge areas. In Western Europe geosyncline deposits, wide fields of the oldest pre-Cambrian gneisses crop out in the Central French plateau, Bogezi the Schwarzwald, Bohemia, the axial part of the Alps from Genoa to the meridian of Trieste, the Balkans and in a series of other places. The crystalline pre-Cambrian foundation lies under the Jurassic geosyncline deposits of the Great Caucasus; vast stretches of pre-Cambrian gneisses occur in the Great Himalayas and in Trans-Shimalaya. Archean-proterozoic(pre-upper Proterozoic) crystalline foundations crops out in many areas among the Paleozoic and pre-upper Proterozoic geosyncline formations of the Urel - Tyan'-Shan' regions, in the Mugodzhars, Ulutau, Kokchetau and others. We can observe the same picture everywhere in the folded structures of Siberia and Central Asia.

A study of profiles of the oldest pre-Cambrian crystalline formations of geosyncline regions and especially of the profiles of the Urals, Kazakhstan, Middle and Central Asia leads us to conclude that these deposits are distinguished by: (a) a great thickness, (b) a similar regional metamorphism, (c) widely developed appearances of granitization, (d) complex and rather unique folding appearing in the pre-upper Proterozoic period, (e) sharp contact with covering rocks, (f) consistency and uniformity of geological features which characterize stratigraphic complexes, permitting them to be separated stratigraphically and even to be compared with similar complexes of old shields.

All this brings us to the conclusion that the pre-upper Proterozoic metamorphic foundation is consistent and uniformly developed in the form of a continuous thick sialic covering both in the field of geosynclines and in the field of platforms. The geological phenomena which caused this cover to form remain inadequately investigated, but it is well known that these phenomena are much different from those which took place later. It is sufficient to indicate that the folding of the upper Proterozoic and younger deposits greatly differ from the folding of Archean formations in the following: omnipresent granitization; similar regional metamorphism in all continents so characteristic for the old pre-Cambrian period, is altogether absent in the post-upper Proterozoic period; great differences in metallogeny, magmatism, sedimentation, etc.

Although not going deeply into the analysis of the problem, we can quite reasonably say, that we must not confuse pre-upper Proterozoic with later development if we wish to clarify and work out principles of development based on a knowledge of observed natural phenomena. We cannot consider as geosynclinal the pre-upper Proterozoic development of the structure of the earth's crust which culminated in the formation of the continuous but probably not completely homogeneous thick sialic covering of modern continents. We shall not study it here, but we shall conditionally separate it into a special and, for the most part, still unknown stage in the development of the earth's structure at a time when geosynclines and platforms characteristic for the upper-post Proterozoic stage did not exist.

After being formed, the pre-upper Proterozoic sialic covering, which may be called a platform ("panplatform"), later underwent a different history in different places. In some regions immediately after formation it broke up into sub-surface fragments and turned into a geosynclinal field. In other regions it remained stable for a long time, being covered wholly or in part by platform sediment, after which it was drawn into geosynclinal development. Finally, as a third possibility, it remained relatively stable up to our time: such parts of the earth's crust bear the designation of old platforms or stable fields.

By keeping to the concepts just stated, we can easily determine when almost every geosyncline field was layed and follow all further phases of its development.

3. PHASES IN THE DEVELOPMENT OF GEOSYNCLINE STRUCTURES

By studying first of all the post-algonian geosyncline fields of Eurasia, located within the boundaries of the USSR -- in the Caucasus, in the Urals, Kazakhstan, Middle Asia and Siberia -- we can isolate several phases in the development of those structures. These are characterized by a special paragenesis of sedimentary, and magmatic formations by special folding andorigin.

There are three different phases in geosyncline development: (1) primary geosyncline systems, consisting of geosyncline troughs and intervening platform projections, (2) secondary geosyncline systems frequently in the form of troughs ("brachygeosynclines"), which are separated by elevations -- geoenticlines, and (3) residual geosyncline systems, characterized by alternation of vast flat cavities and sloping bulges.

Primary Geosyncline Systems

General morphology.

Primary geosynclines are linear, long and narrow, frequently asymmetrical furrows in the earth's crust separated by similarly narrow and long intervening platform projections. According to this very characteristic morphological feature, primary geosynclines can be known as geosyncline troughs.

Primary geosyncline systems usually consist of several narrow furrows and intervening projections (the Urals), less frequently of a single more significant furrow (Southern Tyan'-Shen').

It is supposed that primary geosyncline systems and the folding belts arising from them started to develop only in connection with sub-surface fractures. Older complexes of the pre-Cambrian period are characterized by a complex tangle of dislocations, consisting of fine wrinkles with a zig-zag type of curving hinges. They probably do not have the large regional fractures which give linearity to the folding zones; only the upper Proterozoic geosynclines which border the Eastern European and North American platforms, according to the observation of N. S. Shetskiy, reveal surprising direct linearity and are accompanied by sub-surface fractures in the crystalline foundation. The Paleozoic and the Mecocainozoic geosyncline systems are connected in their development solely with belts of sub-surface fractures which gives them a unique furrowed appearance.

Formations of effusive and sedimentary rocks.

Primary geosyncline systems are accomplished solely by sea deposits at an overall thickness of up to 8 - 10 kilometers. The following paragenetically connected formations are characteristic. Underwater-sea outpourings, chiefly of the fundamental lava (a spilite-keratophyre formation) and the products of vulcanic eruptions associated with them make up the lower part of the profile of a primary geosyncline. With the vulcanic rocks are siliceous and silico-clay deposits, frequently represented by pure jaster (jasperite). Then there usually follow very thick terrigenous sea gray-colored deposits -- graywacke sandy and clay shale above which there usually is a formation of reef and pelitomorphic limestone. For some primary geosynclines, the upper half of the profile is represented by a flysch formation. However, the sequence of the deposits of the formations and their composition does not always maintain the order just indicated. At times vulcanic rocks interchange with synchronous reef limestone, silico-clay rocks and graywecke. In some cases, one or another of the formations enumerated are absent altogether, however, new contra-indications will never appear in their places -- such as a formation of supercrust porphyritic eruptions, or formations of red-colored lagoon-continental deposits or saliferous, carboniferous formations, etc.

In primary geosyncline system furrows are separated by intervening platform projections which either lag behind in general subsidence or do not undergo it at all. Sediments which accumulate on these projections are distinguished by their small thicknesses and large gaps; they have the same designs as furrows, but show a higher content of carbonaceous and coarse-fragmental rocks. On the edges between the projections and the furrows, there is usually observed an abrupt increase in thickness and a rupture of the environment when the profiles have no structural connections. Geological mapping and analyses of the zones where projections and furrows come together are a means of revealing the demarcation of sub-surface fractures and of deciphering the history of their development.

The intervening platform projections of primary geosyncline systems should not be confused with geoanticlines which develop into a phase of secondary geosynclines. They differ from them by the absence of acid intrusions, corresponding to the given phase of development of denudation and along with this by the absence of complex horizontal zonality of the environment within the boundaries of the projections.

Magmatism and mineral formation.

Phases of the primary, secondary and residual geosyncline systems exhibit the same deep differences in regard to magnetic phenomena and metallogeny as they do in the character of sedimentary formations.

In order to understand the historical and genetic succession of the phenomena of magmatism in primary geosynclines (geosyncline troughs as distinguished from the platforms on which these furrows arise, it is necessary to deviate somewhat and give a brief description of platform magmatism.

In platforms, just as in geosynclines, magmatic action appears in connection with deep cracks of the foundation which are capable of penetrating from the depths to the surface. Depending on the presence and thickness of the sedimentary hood and the condition of its permeability, magmatic products can freely flow to the surface in the form of lava or can form blind bodies inside the hood and on the surface where it comes in contact with the foundation.

In general, owing to the small thickness of the sedimentary hood of platforms, all intrusive bodies of these tectonic fields are distinguished by slight depth of stratification. A. A. Polkanov and G. Cloos have shown that a considerable part of platform intrusions appears as sub-valcanic which, in some phases of its development produced effusive eruptions, in others -- closed bodies. As an example of similar sub-valcanism, we shall use the well known Lovozerskiy massive of the Kol'skiy Peninsula, which in the beginning phases of development, embracing basic and particularly alkaline stages of magmatic evolution, underwent supercrust eruptions and in the final phase, which corresponds to the ultra-alkaline stage of evolution, became plutonic, isolated from the old surface by internal effusive-tuff thicknesses. Similar occurrences of close interlacing of effusive and intrusive forms, arising from one magmatic seat, are widespread in the traprocks of Siberia, Dekan and Abyssinia, in the Rapakivi granits of Finland and the Ukraine. In a somewhat different aspect this intermeshing is observed in geosynclines.

Intrusive complexes of platforms are characterized by extreme differentiation and multi-phase development. In them are combined the ultra-basic acid and ultra-alkaline products of magmatic evolution. Moreover, it is not rare to find monomineral formations, which present isolation of the basic plagioclase (anorthosite), pyroxene (pyroxenite), horneblends, apatite, nephelene, calcite, etc. Products of separate phases of magmatic evolution in some instances occur separately in the form of independent bodies, in other cases - in series up to five or six units, constituting complex (multi-phase) bodies. The direction of magmatic evolution in intrusive complexes of platforms is expressed by the following sequence of intrusions: ultrabasic and basic acids ultra-alkaline. In separate regions where the platform type of plutonic rocks develop, the whole evolutionary series is not usually represented - only some of the links. In South Africa, for example, products of the ultrabasic and basic phase prevail; in the Khibins - the ultra-alkaline phase is dominant; and in the South Baltic shield - the acid phase (Rapakivi and quartz porphyry). The reason for this lies in the general tendency of the tectonic development of each region. The ultrabasic and basic magmatic complexes are connected with the development of negative regional structures, in whichnthey form (in the presence of interlaminated intrusions) sill and lapoliths, and when intrusions are present - dikes. The intrusions of ultra-alkaline rocks coincide with periods of elevations and are usually seen in domes in the form of central type compound plutonism.

The extrusive platform series reveal a very high degree of differentiation. They differ from the comparatively homogeneous spiliteceratophyre masses of geosyncline troughs and porphyritic masses of secondary geosynclines by containing elements of a diverse nature and vary in composition from picrites and basalts to phonolite porphyrites.

The crystallization of platform intrustions goes on in a quiescent tectonic condition, favoring the development of the peculiarities of texture and structure specific and inherent in these intrusions. The shift of the crystallizing magma inside a tectonic hollow which is not constrained by outside pressure seems favorable for exceptional development of structures of the flow (the plane-parallel orientation of minerals, fluidity, lamination) which repeat the form of the space being filled up and favor wide development in basic rocks of the processes of displacing minerals of earlier phases of crystallization by later formations, and in acids -- of processes which explain the appearance of such structures as Rappakivi and granophyre.

In intrusive platform complexes, the acid series of magmatic rocks is represented exclusively by Rapakivi and by red granophyre granite. The first were developed chiefly in old complexes, the second in younger ones. Rapakivi and granophyre granite are not known in intrusive complexes of folded regions; normal granites are absent in platforms. The essential differences in mineral and chemical composition of the group of Rapekivi lie in the fact that granophyre granite and groups of normal granites do not appear. Basically these groups differ according to type of structures. The first groups are characterized by much earlier formation of the orthoclase in relation to the plagioclase and by the graphic intergrowth of feldspar with quartz (in granophyre granite). The second group is characterized by the opposite ratio of the crystallization periods of the orthoclase and plagioclase and by the absence of graphic intergrowths.

Crystallization of feldspar fusions produced under laboratory conditions has indicated that in the absence of pressure potash feldspars are isolated first in the fusion. When strong pressure is applied, the order of crystallization is destroyed; lime-soda feldspars are the first to become separated, then come potash feldspars after some delay in the process of crystallization.

The geological conditions for finding Rapakivi and normal granites show that the former, representing intrusions of platform regions, hardens in a quiet tectonic condition, and the latter, being intrusive formations of folding zones, are crystallized under conditions of strong regional stress. We see that the data of laboratory observations completely coincides with conclusions derived from analyzing the tectonic situation forming these rocks.

Magmatism of primary geosynclines (geosyncline troughs) especially in the initial phase of development, shows a similarity to magmatic manifestations in platforms. In primary geosynclines, the intrusions of metamorphic basic and ultrabasic rocks (ophiolites) and the thick spilite series are wide-spread. Both of these groups of erupted rocks usually coincide with siliceous and silicoschist thicknesses, located in the lower half of the geosyncline trough profile and, as a rule, precede graywacke and flysch. In the island arches of the Zondiskiy archipelago and in Burma ophilotes are related to the Cretaceous and in the Alps they are still earlier (Triassic). In the Hercynides of the Urals, they conform to the Gothlandian and the Devonian (They are also known in the Carboniferous, where they have a somewhat different character.); in the Hercynides of Southern Tyan'-Shan' and Alay to the Gothlandian; in the Caledonides of Northwestern Europe to the earlier Ordovician; in the Salarides of Siberia to the lower Cambrian, etc. In Paleozoic geosynclines, just as in the Alpine, ophiolites occur among the thicknesses of spilite-ceratophyre, graywacke-schist and the limestone series.

In intrusive complexes of primary geosynclines, particularly in the greenstone geosyncline of the Urals, earlier intrusions represent extremely differentiated monomineral formations, (dunite, pyroxenite) which are absolutely identical to corresponding platform plutonic rocks, but the succeeding, less differentiated intrusions (gabbro) in their general nature stand closer to homogeneous intrusive folding zones.

A similar direction of magmatic evolution is detected also in the extrusive series of geosyncline troughs, beginning usually with picrite and diabase porphyrites and ending with andesite porphyrites (South Tyan'-Shan' and Alay). Acid and alkaline rocks in geosyncline troughs as a rule do not have development, and magmatic evolution, leading at first in the platform phase, breaks off on the first stage producing basic and ultrabasic products. In some geosyncline troughs (greenstone depression in the Urals, the Caledonian Chingiz) vulcanic activity lasted longer and partly delayed succeeding stagesof magmatic development, during which period quartz, albiotophyre and ceratophyre lava appeared.

Intrusive bodies of geosyncline geosyncline troughs, similar to platform plutonic rock, are of relatively small size and are characterized chiefly by sill morphology. They are differentiated from their platform analogues by sharing in succeeding folding deformations along with sedimentary thicknesses which fill the troughs. As a result of this, intrusive bodies are characterized also by very strong dynamic metamorphism, which is expressed in almost completd serpentinization and uralitization of the primary mineral components (olivine, pyroxene). When crumpled, sills of opiolite not infrequently disintegrate into individual lenses and phacolites which are timed to anticline ridges.

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Contacts of ophiolite bodies usually undulate in agreement with the schist nature of lateral rocks. The arrangement of ophiolite intrustions is typically in the form of narrow belts of a large number of bodies, stretched along the subsurface fractures of geosyncline troughs. Such belts of ophiolites stretching out for thousands of kilometers, are connected with the Alpides of the insular curves of the Zondskiy archipelago, with the Hercynides of the Urals, with the Caledonides of Norway and with many other fields of similar tectonic system.

It is known that the tectonic system plays an exceptional role in hypogene ore formation. Probably every magmatic fusion contains metallic elements, but the geological situation and system into which this fusion falls does not always turn out to be favorable for their isolation.

Actually, in some situations the geotectonic system favors the differentiation of magmatic fusion and the separation of the component parts of ores; in others, however, it hinders the process and holds the metallic elements back in the magma. Also, the geological medium surrounding the intrustion sometimes turns out to be impervious to ore-bearing emanations, and at times contains cavities, which permit circulation and mineral formation. Therefore, in regions of different tectonic systems mineralization is represented by different types.

Under platform conditions, magmatic fusion evolves in a quiescent condition, which favors its extreme differentiation. In ultrabasic phases, which form sills and lopoliths, metallic components are separated from the magmatic fusion as a result of crystalline differentiation and possibly partial liquation in the form of ore horizons, streaks and seams, which -- when the mass hardens -- remains in the gangue. Typical ore formations of intrusive platform complexes are copper-nickel sulfides, platinum and, in part, chromites (Sedbury, Bushvel'dskiy complex). Thick deposits of magnetite which contain the characteristic admixture of spatite are frequently associated with acid phases. Ultra-alkaline phases, which are often observed in the form of compound central type plutonic rocks, contain strong concentrations of apatite, nepheline and various rare earth minerals, forming streaks, cavities and even independent intrusions.

Magmatic fusion evolves in a quiet condition favoring differentiation under conditions of the beginning phases of primary geosynclines (geosyncline troughs), a system which emerges from the platform and develops with increased mobility. In the first stage of the development of a geosyncline trough, while its tectonic system retains features received from the platform, there arise ultrabasic and basic products of the differentiation, which form sills. When the fusion solidifies a concentration of ore substances arise in the sills in the form of deposits, ore horizons, seams, etc. Separation of ores from the silicate magma place through liquation and crystalline differentiation by which some of the metallic components from segregated accumulations, whereas others, form a concentrated residue. The latter sometimes undergoes shifts of the internal gangue intrustion and in these cases turns into vein-like deposits (chromite beds of the Urals).

Typical beds of geosyncline troughs are chromite, platinum, titanomagnetite and pyrite. When a folding appears in geosyncline

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troughs, ore deposits of this genetic group are subjected to dislocation and metamorphism just as the rocks that enclose them are. Ore bodies laminate and form folds, and the substances composing them undergo transcrystallization, accompanied by metamorphic differentiation. This causes cavities to appear in the ore, which agrees with the foliated structure of the lateral rocks. The folding deformations, which have been noted, and the metamorphism of ore bodies in the beds of geosyncline troughs, which have been thoroughly studied in recent years through pyrite deposits of the Urals, show their chief distinguishing feature which is not peculiar to beds of other genetic groups.

Typical beds of sedimentary ores of primary geosynclines are beds of hydrogothite-schaumozite iron ores, beds of manganese and iron-manganese ores and sea bauxites. All these beds are formed by sedimentary means, but the origin of the mineral substance in them is apparently very closely connected with phenomena of volcanism or post volcanic processes.

Metamorphism and Folding.

Rocks of the primary geosyncline systems are always distinguished by considerable displaced metamorphism. The volcanic formations in them changed, transformed into greenstone rocks, and the clay-sand deposits into phyllites that are very similar throughout the geosyncline system.

Folding of the strata that filled in geosyncline troughs, are characterized by fine, strongly compressed equidimensional anticlines and synclines with narrow locks, steep sides and "plunging" joints. In foliated thicknesses, isocline folding and systems of inclined folds tending towards platform masses, are usual.

One's first impression is that simple and complex folding of geosyncline troughs is the result of a single tectonic act. In reality there is adevelopment lengthwise from zone to zone. The first folding formations form small internal elevation -- ranges, which in succeeding phases, gradually fill in the whole geosyncline by accumulating new folds. Consequently, the development of the folding structure of the thicknesses of geosyncline troughs goes on simultaneously with the sediment accumulation and with the peneplaining of the folded mounts in ranges which arise inside of them. It is usually believed that by the time a geosyncline system is finally completed a large uplift with a broken relief is formed as a result of the folding. In reality, the reverse is true: the cessation of folding and sediment formation coincides with the period when the tectonic relief completely levels off. This is perfectly natural since relief formation, sediment accumulation and folding are interconnected through a single, although irregular, flowing process of the structural development of any geosyncline zone. It is necessary to reject vigorously the incorrect concepts which hold that relief appeared first, then sediment accumulated, and after this, folding took place. In nature there are no independent epochs of uplift, of fluctuations, etc, which can be considered apart from sediment accumulation and folding.

Using Tyan'-Shan' as an example, N. M. Sinitsyn has pointed out that regardless of prevailing concepts, the Hercynian fold was completed in the Permian and not by orogeny, and the plain formation is peneplain. No mountains arose in this region as a result of Hercynian folding. The broken relief, sometimes very sharp, takes place only when geosynclines develop during great accumulation of sediment and folding.

The concluding epoch of the primary geosyncline system is usually shown by the exclusion of almost the whole system of sediment accumulation, by the weakening of folding and by a flat (or almost flat) relief. This condition is important since it permits an approach towards evaluating the general results of large structural transformation of the earth's crust, appearing as a result of the primary phase of geosyncline development. In reality, if primary geosyncline systems appear on a platform (we shall dwell on this later), that is, a plain, and if their development ends as a plain on which secondary geosynclines develop later, these two surfaces can be definite data marks for any structural formations. By the end of their development primary geosynclines are complex folding zones having separate geosyncline troughs in which the platform base is lowered and is 5 - 10 kilometers deeper than in the intermediary projections and in the adjoining parts of the platforms. The depth of the lowering must be on an average not less than the thickness of the deposits, which fill up a geosyncline trough. No reversing -- inversion -- takes place during the completion of the period of geosyncline troughs if the appearance of the completion of folding and sediment accumulation and the development of a flat relief is not taken as the inverse.

From what follows it will be evident that thick folding scars which arise on geosyncline troughs at times are insufficiently stable, and during the secondary geosyncline development phase are pressed upwards. However, despite all succeeding changes (significant elevations and denudation) even the oldest (lower and middle Palezoic folded geosyncline troughs remain in the structure of the earth as irreversible non-destructable elements (the greenstone geosyncline of the Urals and Southern Tyan'-Shan', etc).

Folding develops irregularly in the primary geosyncline system and its intensity changes sharply from place to place. In intermediary projections, especially in very wide ones, crumpling is considerably weaker than in neighboring geosyncline troughs, or is absent altogether. It is usually observed that they have cavities of normal folding, alternating with narrower cavities which lack normal folds, where all the layers are faulted, disintegrated, have broken seams and foliation, and are more strongly metamorphicized. The irregularity of the dislocation and the localization of the greatest crumpling in narrow zones are connected with subsurface fractures and with the nature of their special distribution. The fields of greatest crumpling of a geosyncline system gravitate towards the subsurface fractures. Masses of magmatic rocks are frequently distributed along these fractures; in their furthest development they frequently serve as axes of uplifts and ridges. In other more simple instances, fractures are distributed along the border of a geosyncline trough with an intermediary projection, or along the edge of a platform. A similar distribution of subsurface fractures always takes place in asymmetrical geosynclines.

The Origin of Primary Geosyncline Systems.

It has been noted several times that geosyncline systems characterized by the morphology just described -- formations of sedimentary and magmatic rocks, mineral resources and folding -- appear on a platform base as a result of the disintegration of the belts of subsurface fractures. We have called these new tectonic formations primary geosyncline systems.

In order to show that primary geosyncline troughs and intermediary projections actually arise on platforms, it is necessary to give several brief examples.

The example which best shows the origin of geosyncline troughs inside a platform is the Alpine mobile belt encompassing southern Europe and the northern fringe of Africa, Asia Minor, Iran, Hymalaya and the island chain of the Zond Archipelago.

In most places of the Alpine belt, thicknesses and intricate displaced deposits of the Mesocenozoic complex are distributed on a platform base made up of gneisses covered by a small hood of Paleozoic sediment which is typically platform in appearance. That is why in all large elevations of the Alpine belt there are old gneisses side by side with a mesocenozoic geosyncline complex, and only sporadically are there insignificant blocks of slight Paleozoic thicknesses that did not undergo geosyncline crumbling earlier. In other very limited places (the Black Mountains, Karniy Alps) conditions evidently developed in the Paleozoic which can be treated as geosynclinal. Likewise, the well known profile of the Black Mountains, which has thick schist, limestone and marl deposits from the Cambrian to the lower Carboniferous, requires special study and interpretation.

In Western Europe, the outcropping of gneisses stretch along the northern front of the Alps from the Central France Plateau through Vorezy, Schwarzwald and Bohemia to Vienna and along the axial zone of the Alps from Genoa to the meridian of Trieste.

The northern belt of gneisses and crystallized schists, known to German geologists as Moldanubian, probably constitutes the western continuation of the Azov-Podol'sk block of the Russian platform. In the Paleozoic the Moldanubian strip underwent elevation, interrupted by short transgressions in the middle Cambrian and Gothlandian. In the central and southern zones of the Moldanubian strip sediments of the Paleozoic almost did not develop; and in the northern zone, bounded by the Hercynian geosyncline of western Europe, they were expressed by a special type, which has been designated Barrandov of the Paleozoic. The latter is characterized by a rather thick Cambrian, Silurian and Devonian development, weak metamorphism and simple forms of displacement. The caledonian fold does not appear at all in the Moldanubian strip. In the Hercynian phase, this strip, having appeared on the edge of the Western European geosyncline, was subjected to cleavage; even in the Barrandov complex, the Hercynian displacements have a block-folding character. The unusualness of the structural development of the Moldanubian zone is reflected also in the character of its magmatism. In it are represented extreme members of the acid series of magmatic rocks; they are exceptionally poor in calcium and have an increased potassium content. According to investigations by Cloos, the plutonic rocks of the Moldanubian strip have the form of steep sloping interformational intrusions, the roots of which are distributed in fractures (massifs of the Passau Forest, Lausitz, etc). In the Carpathian sector, the Moldanubian gneiss mass is submerged under young sediment of the foothill hollow and then crops out anew in the Azov-Podol'sk uplift.

Earlier investigators considered the internal strip of gneisses of the Alps (Pennides) to be the central crystalline axis of the range - its old skeleton. Later, during the period when the concept of mobility prevailed, - concepts still not overcome by foreign geologists even at present -- there appeared fantastic diagrams and profiles by Argan, Shtaub and other authors, showing the Alps in the form of a system of an overthrust mass in which a gneiss core occupies the position of a median deposit formed by the same thicknesses of the Alpine sedimentary complex, only more deeply metamorphisized. In the French Alps, which have a less complicated folding structure, there is a non-conforming overlap of the Alpine geosyncline complex of deposits, beginning with the Lias series (massif of Belladonna east of Grenoble). We find represented here for the whole Alpine system a true andundoubtedly general relationship between gneiss thicknesses and Alpine geosyncline complexes, which runs decidedly counter to the views of the mobilists.

The structure of the Alps can be presented much more simple in the form of a system of folding troughs, filled with severely crumpled thicknesses dynamically metamorphosized by strata of the

Mesocenozoic age between whose intervals are distributed projections of a shattered platform with a deep layer of gneiss foundation covered -- except for isolated sections -- by a thin shroud of sediment. During the orogenic process the gneiss foundation of these wedges is easily freed from the sedimentary cover and forms vast outcroppings on the surface.

In the Himalayas two strips of Alpine structure, separated by wide strips of gneisses, have been formed. The composition of the northern strip of the Alpides, which embrace the Karakorum Chain, has conformable, crumpled thicknesses of the middle and upper Paleozoic, Triassic, Jurassic and Cretaceous. The Paleozoic parts of the profile are represented chiefly by organogenous and siliceous limestones, and the Mesozoic chiefly by very deep schist and flysch thicknesses. The lower half of the Mesozoic complex has ophiolite intrusions which are characteristic of geosyncline troughs. The southern strip of the Alpides, which stretches from the sources of the Indus to the great emanation of Brahmaputra, ended its formation in latter tertiary times. It is made up chiefly of young sediment, particularly of thick Paleogene flysch.

The Alpides of the Himalayas are distributed among thick strips of gneiss which form the skeleton of the main ranges of this system (the Great Himalaya and the Trans-Himalaya). From the side of Tibet towards the Kerakorm branches of the Himalayas orogen a vast gneiss mass approaches a hollow with a wrinkled hood, which includes deposits from the Cambrian to the Cretaceous periods. In a number of places on the edges of the gneiss masses of the Great Himalayas and the Trans-Himalayas conformable, displaced Paleozoic deposits project out from under the thicknesses of the Alpine complex. In a profile of the Spit valley, deposits have fauna of the middle and upper Cambrian, of all divisions of the Silurian, Devonian, Carboniferous and lower Permian. In contrast to the Mesozoic group, represented in the Himalaya zone by geosyncline thicknesses, the Paleozoic group has features characteristic of platform formations: peculiarities of this group are small widths (the total for the whole Paleozoic is 1800 meters), facial uniformity of sediments, and absence of angular unconformities. The pre-Silurian and pre-Permian movements that appeared in the Himalayas are expressed in these profiles only by stratigraphic unconformities and blocks of conglomerates with thicknesses of 50 and 60 meters. In regard to the lithological composition, the Paleozoic thicknesses of the Himalayas are remarkable for an almost complete absence of coarsely brecciated rocks when there is a wide development of schists, quartzites (partly red-colored) and organogenous limestones. This also characterizes them as sediments of platform regions.

Geosyncline thicknesses of the middle Paleozoic and lower Mesozoic in the southern Pamirs are directly supported by the oldest pre-Cambrian, deeply metamorphic deposits, which even comparatively recently some geologists have related to the Paleozoic or even to the Mesozoic. It is now becoming clear that the upper pre-Cambrian and the lower and middle Paleozoic are absent in these profiles.

Some interesting material on pre-Mesozoic development of the Alpine zone is found in the Caucasus. In the Little Caucasus among pre-Jurassic deposits one can separate two sharply different complexes. The first complex is not represented stratigraphically by homogeneously disintegrated, displaced and metamorphosized deposits: phillites, marbles, various crystallized schists, gneisses and old granites. The outcroppings of this old metamorphic complex are found in the Miskhano-Zangrezursk and Samkheto-Karabakhsk zones of the Little Caucasus, in the Dzirul'sk mass and in the main Caucasus range. It has the typical geosyncline deposits of the Jurassic system everywhere. The age of the foundation rocks is not definite but they are not younger than the Gothlandian. The only proof of the presence in the composition of the foundation of the lower Paleozoic is an old finding of fauna in the skarns of the Dzirul'sk mass. In the ground in a sample of skarn one new form, supposedly of the lower Cambrian archeociate was identified, besides this one. We were not convinced of the reliability and validity of this identification (archeociate), but nevertheless there remains the indisputable fact of an old, possibly pre-Cambrian crystallized foundation occurring in the regions of Jurassic geosynclines.

The second complex of pre-Jurassic deposits of the Little Caucasus developed mainly south of Lake Sevan, where the so-called Armenian "geosyncline" of Hercynian time was located. This complex is interesting because it is characterized by the most typical features of platform formations. In the Sharuro-Dzhul'finsk zone deposits of the upper Gothlandian, Devonian, lower Carboniferous, Permian and Triassic occur without apparent unconformities, although there are interruptions in the deposits of sediments (in the middle and upper Carboniferous). Furthermore, in the

Dzul'finsk region, even the Jurassicoccurs on this complex without apparent uniformity. Here there are not only no geosynclines, but even no noticeable platform displacement of Hercynian time. In the composition of the pre-Jurassic deposits in the region considered, the organogeneous brecciated and also the bituminous limestones are very important since sandstones and schists are subordinate to them. Marls, sometimes red in color, are characteristic of Permian and Triassic deposits; limestones of the Carboniferous are gypseous and among Devonian limestones, there are horizons of nodular phosphorites. No one can have any doubt that the middle and upper Paleozoic as well as the Triassic deposits correspond to platform formations. Here also there is not the typical basic volcanism and dynamic metamorphism for geosynclines; Paleozoic metallic beds are also absent. Consequently, the Armenian geosyncline and the Transcaucasus geoanticline developed without sufficient bases; according to the character of the structural formations and according to the formation of rocks, the first is a typical synclase and the second an anticlase of Hercynian time. Even significant pre-Mesozoic displacements of the Miskhano-Zangezursk zone can be interpreted as platform.

The clearly expressed small narrow isolated geosyncline in the Paleozoic was distributed along the northern slope of the Great Caucasus just where the Mesozoic geosyncline begins to degrade, being replaced by platform formations.

In the Carpathians there is no such defined data on pre-Mesozoic history as in the Caucasus, but it is very interesting that in the outcroppings of the pre-Mesozoic foundation, neither the Hercynian or the Caledonian has been detected. The foundation there is probably older.

The examples of the Alps, Himalayas, Pamirs and Carpathians indicate that the most powerful mobile belt of our planet over most of its area (but possibly not everywhere) was a stable region to the end of the Paleozoic, serving as a coordinating link between the present disconnected Russian, African, Chinese and Hindustan platforms. This region acquired great mobility only in the Mesozoic (in places in the upper Paleozoic) when within its territory a system of thick subsurface fractures appeared, which was the start of the Alpine geosyncline troughs.

The disintegration process of the pre-Cambrian platform base and the formation of differently constructed geosyncline systems of the Caledonian, Hercynian, Ienshansk and Alpine ages can be illustrated by numerous examples from the geology of Asia. For example, the well studied and widely known history of the disintegration in the Mesozoic of the Chinese platform, although an old concept, has been confirmed with new facts by N. P. Keraskov on the platform development in the lower and middle Paleozoic of the Verkhoyansk-Kolymsk Mesozoic folding zone, etc.

Geosyncline systems arise when platforms disintegrate in belts of subsurface fractures. Primary geosynclines are narrow depressions (ditches) with a platform base, and the intervening projections are weakly mobilized sections of a platform between them. It is clear that primary geosynclines are of numerous varieties. Sometimes they shrink, sometimes they expand, then finally they disappear completely within the platform (the Great

Caucasus, the South Urals, etc). Sometimes a large belt of fractures stretches out, branches encompassing large fragments of the platform -- the so-called central mass, or small intergeosyncline (partly mobilized) platforms. Apart from morphological peculiarities, primary geosynclines can be differentiated also according to other features: by formations of sedimentary rocks, magmatism and metallogeny, but these differences are of a partial nature and appear singly or in extreme instances in two features. These differences are always possible and force a classification of geosynclines to be made not on the basis of a single feature but on the whole complex of signs. One should not isolate genetic types of geosyncline structures only on the characteristic of folding or by the relationship of thicknesses. The most important classifying feature is the paragenesis of sedimentary and vulcanic rock formations. This is the deciding factor, especially in those instances when platform formations are overlapped by geosynclines and appear along with those which have been metamorphisized and displaced.

A new decision on the problems of the deposits and development of the upper Proterozoic and Paleozoic geosyncline systems of the Urals, Kazakhstan and Tyan'-Shan' can now be given after deciphering the stratigraphy and age of old formations of these regions. The Ural-Tyan'-Shan' geosyncline region is especially interesting because here we can fairly well study the upper Proterozoic phase of structure development and thus can establish the connections between pre-Cambrian and Paleozoic development.

At the end of the upper Proterozoic phase of development, simultaneously with the last great phases of folding, almost the whole territory of the Russian platform, the Urals, Kazakhstan and the Tyan'-Shan' was cut off from sediment accumulation and turned into a long lasting folded plain. The Cambrian is of limited occurrence in the Ural-Tyan'-Shan' region. It is found in the western part of the Southern Urals (west of the Murodzharsk uplift), in the Turkestan Kara-Tau, on the western slope of Ulu-Tau and in the mountains of the Southern Tyan'-Shan', but on the eastern slope of the Urals, in central Kazakhstan (except for its northeastern parts) and in the northern Tyan'-Shan' the Cambrian is completely absent. True, many geologidts even at present still relate upper Proterozoic formations to the Cambrian and Ordovician or simply to the lower Paleozoic, since new data and the conclusions based on them are too recent yet to become known to the majority of geologists. However, new data already partially published is so clear that it definitely shows that upper Proterozoic deposits and structures of the northern Tyan'-Shan', Kazakhstan and the Urals should not be included in the lower Paleozoic and Caledonian.

Comparatively great sediment accumulations took place in the Cambrian, but evidently only in very narrow depressions along the western slope of the southern Urals and in the system of the Turkestan Kara-Tau. In Kara-Tau, deposits are represented by large terrigenous, (lower Cambrian, in places motley colored) and limestone-dolomite formations which in their general character are reminiscent of marginal depressions (in this case of the depression which is distributed along the edge of the upper Proterozoic folding region of Central Kazakhstan). In the system of the southern

Tyan'-Shan' (Turkestan and Alay ranges, Nura-Tau) the Cambrian and Ordovian which lie in the base of the Gothlandia geosyncline are of a platform nature. They are represented here by a homogeneous thickness of sand and schist (with marls and thin layers of limestone), by general thicknesses of no more than 1000 meters; among them there is no evidences of vulcanic rocks; displaced and metamorphosized, these deposits are located with the Gothlandian and the Devonian. On the other side of the Karatausk depression -- in the region of central Kazakhstan -- during the whole Cambrian a flatland spread out which was inundated in the eastern part during the middle Cambrian from the side of the Siberian platform by a shallow sea. Thus it is clear that there is no Cambrian geosyncline in the composition of the Caledonides of central Kazakhstan, northern Tyan'-Shan' and the eastern part of the Urals (beyond the Mugodzhari). Profiles of the Ordovician in places are also reduced and in large areas are absent altogether. Other features (volcanism, metallogeny) similarly testify to the underdeveloped character of the Caledonides of the Ural-Tyan'-Shan' region, where except for the Chingiz and Terseysk zones typical geosyncline troughs of the lower Paleozoic age do not appear. On the other hand, by the time of the Gothlandian, we see a clearly expressed system of secondary geosyncline development (the basin system) which prevailed during the whole Hercynian phase over the whole territory of central Kazakhstan.

The upper Proterozoic chronologically and according to the character of development are a connecting link between the old phase of forming a metamorphic cover (a platform) and a younger geosyncline phase. Therefore, in many regions (Ural-Tyan'-Shan' region, Hercynides of central Europe, etc) where the upper Proterozoic structure reveals all the features of primary geosynclines, the latter either does not appear in the Paleozoic or, having appeared, show a degrading feature in their development. So completely are secondary geosyncline systems developed in the upper Proterozoic that they appear in many regions of the Hercynides of central Europe, the whole Hercynian of central Kazakhstan, northern Tyan'-Shan' and other regions.

Secondary Geosyncline Systems

Secondary geosyncline systems arise and develop on those territories which already have, in one form or another, passed through a phase of development of primary geosyncline systems.

[In some cases secondary geosynclines do not develop from primary systems, but from the syneclase of platforms, which have gone through a long and intensive lowering before this. Examples of this kind are found on the Pacific coast of Asia].

Being in historical and special succession with primary geosynclines, secondary geosyncline systems inherit a series of structural peculiarities from them in the form of the main tectonic lines, scarred but still not extinct zones of subsurface fractures, some depressions and uplifts, and in connection with this, trends of folding. In general, it must be noted that of all the elements, the trend of tectonic structure, that is, its plan, is most constant and is easily transferred down from one structural stage to another. As an example, we can take the structures of central Kazakhstan, where in secondary geosynclines of the middle

Paleozoic we can see inherited structural trends of the upper Proterozoic base, despite their complex "meshed" character. However, along with this heritage, a substantial change-over of structure is also noted. New tectonic elements arise, and the whole complex of geological phenomena changes sharply: relief, sediment accumulation, folding, volcanism, mineral formation, etc. The unique character of geological development of this period causes it to be divided into a special phase, peculiar to all moving belts of the earth -- the phase of secondary geosyncline systems.

Let us go over to a brief description of secondary geosyncline systems.

General Morphology.

In dimension and form, secondary geosynclines are extremely diverse. Their prevailing forms, especially in zones of development of intensive upper Proterozoic folding, are large isometric depressions, greatly extended in length or cup-shaped. These forms, according to morphological criteria, can be called geosyncline basins or brachgeosynclines. Marginal depressions evolve as a special kind of secondary geosynclines. They have many characteristic features (paragenesis of formations, folding, etc.) and are distributed parallel to locked primary geosynclines and therefore also possess linearity which is preserved over a great expanse and in widths of 50 - 100 kilometers.

Secondary geosyncline system which inherit Caledonian and Hercynian geosyncline ridges and troughs reveal linearity, however, it is less expressed. Some very large isometric geosyncline basins attain several 100 kilometers in width. Their central parts frequently lie on wide planes of intervening platform projections of primary geosyncline systems having the character of median masses.

In cross section, geosyncline basins and marginal depressions are almost always asymmetrical. Their edge, adjacent to the more abrupt, short wall of the asymmetrical uplift, is more hollow.

There are two types of geosynclines in secondary systems: (1) geoanticlines, which inherit intervening platform projections of primary systems and (2) geoanticlines, newly formed on fractured or interfractured seams of primary geosyncline troughs. Geoanticlines of both types, as distinguished from inter-trough platform projections of primary systems, are zones of uplifts, expressed sharply in the relief. Usually these are narrow, long rising crests, subject to denudation.

Formation of Extrusive and Sedimentary Rocks.

The paragenetic series of formations of rocks of secondary geosyncline systems differ sharply from formations of primary systems. In primary geosynclines sea deposits are exceptionally developed, whereas in secondary geosynclines, along with sea deposits, there are continental and lagoon deposits which have a large over-all thickness (2-10 kilometers). Following are their characteristics; molasse, terrigenous red colored continental-lagoon rocks, saliferous, carboniferous organegenous brecciated limestones, porphyrite (absent in advanced depressions) and terrigenous grey-colored sea deposits (in places typical sea molasse). Limestone thicknesses are usually distributed low down in marginal

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depressions; up above are saliferous and red-colored rocks, replaced under different climatic conditions by grey-colored carboniferous rocks. Continental deposits, in the form of wide ground eruptions chiefly of acid vulcanic rocks, and the coarsely brecciated thicknesses accompanying them are very common in geosyncline basins and are under limestone thicknesses in the lower parts of the basin profile. The upper Gothlandian and Devonian deposits of central Kazakhstan are typical in this respect. Some of the formations mentioned may be absent in individual profiles, but in any event, formations typical for primary geosyncline systems (jasper spilite-ceratophyre, etc) never appear here. It is necessary to keep in mind that when we speak about the absence or presence of a given formation, we do not refer to any separate rock, but to a formation, as a complex of paragenetically connected rocks, which have arisen under complicated physico-geographic and tectonic conditions. Every geologist knows, for example, that the formation of ground surface eruptions, which we call porphyrite, apart from acid rocks contains a certain amount, and sometimes even a considerable amount, of basic rocks of andesite composition. Also, when we speak of formations of organogenous-brecciated limestones, other rocks are not completely excluded from this complex -- such as limestone schists, sandstones, pelitomorphic limestones. The same appliesto mineral formations, In determining the type of formation it is necessary to find the chief determining type of rock, and also it is absolutely necessary to consider the location of a given complex among other formations in the stratigraphic profile. Deposits of secondary geosyncline systems are distinguished by the complexity of facial changes, by the loss of individual strata from profiles, by the multiplicity of fine locally appearing interruptions and local non-conformities. Interruptions and non-conformities are especially significant in the field of geosynclines. These features of sediment accumulation are connected, as we shall see below with unusual features of folding and relief in secondary geosyncline systems.

Magmatism and Mineral Formation.

The division of geosynclines according to system of development into primary, secondary and residual raises the question: to which of these types do the so-called batholitic bodies of eruptive granitoids which represent idispensable elements of almost all of the mobile zones of the planet belong?

Materials, according to a number of geosyncline regions, in particular the Tyan'-Shan', Kazkhstan, Urals and Caucasus, which we know through personal investigations, permit us to come to the conclusion that in primary geosyncline systems, characterized by the maximum appearances of geosyncline tendencies, batholitic bodies of granitoids do not develop; but, on the contrary, they are found to be extremely widespread in secondary synclines; the weakening of the geosyncline system is due to this.

In primary geosyncline troughs, filled with a very thick graywacke-schist, flysch and jasper series, crumpled into systems of fine steep folds, intrusions of granitoids, close in age to the given folding, are absent; or, if these regions in the past have passed through the phase of development of secondary geosynclines, they appear in connection with new conditions of a geotectonic system.

Intrusions of granitoids are completely absent in the Hercynian trough of southern Tyan'-Shan' which is filled with middle Paleozoic thicknesses of siliceous schists, and also graywacke-schist thicknesses (apatolkan series), and upper Paleozoic flysch (axaisk series) an overall thickness of up to 9000 meters and very intricately crumpled. A similar picture is observed in the tectonic zone of the Turkestan range. In the Kokshal'sk zone which is characterized by fine geosycline folding of the middle Devonian age there are found some comparatively small masses of granites, breaking the basin formations of the lower Carboniferous.

In the Chingiz zone of Kazakhstan, granitoid intrusions, coupled with Caledonian folding, which appeared here in forms typical for geosyncline troughs, are absent, but they are widely represented in the Hercynian structure which developed under conditions of the basin system. Finally, in the northern curves of the Tyan'-Shan' which are characterized by geosyncline folding of the end of the Proterozoic with reduced Caledonides and with a basin of the middle Paleozoic there are almost no intrustions connected with upper Proterozoic structures, and very many Caledonian and Hercynian intrustions. Therefore, it is not accidental that the classical regions of a basin system Kazakhstan from the Gothlandian to the middle Carboniferous and the Urals in the Carboniferous and Permian -- are regions of exceptionally large distributions of Hercynian granitoids.

Let us turn our attention to the absence of younger granitoid intrusions of the batholitic type in the so-called exterides of the Alps, Southern Iran, the Great Himalaya and the Zond

Archipelago which present typical geosyncline troughs with thicknesses of flysch and the andesite series, ophiolite intrusions and a very complicated folding structure. The assumption which permits young granitoid intrustions to occur in these zones at a depth not reached by contemporary erosion shearing has no proof behind it, because in the Alps, the mountains of Southern Iran and in the Himalayas, there are instances of gashes of river valleys into the Alpine folding structure at a depth which exceeds the proposed level of stabilization of batholiths (2-4 kilometers). Along with this, in the Karakorum zone of the Himalay orogen, where the primary geosyncline development phase ended by the upper Cretaceous and followed by conditions typical for the tectonic system of secondary geosynclines, young batholitic bodies of eruptive granitoid usually appear.

In secondary geosyncline system, batholiths of eruptive granitoids are subjected to main uplifts. This takes place in the chief arrangement of batholiths in cases of anticlinoria, coinciding with the extension of the batholiths and of the orientation of the elements of their internal structure with the trend of regional tectonic units, in batholiths wedging out on sectors of attenuated anticlinoria, etc. It is very probable that the batholitic bodies of granitoids which develop in anticlinoria not only utilize them as a favorable structure but even help the development of these structures by strengthening the distention of the anticlinorium.

A number of peculiarities in structure of batholite bodies of granitoids are evidence that their formation occurred under conditions of constant regional stress. In particular this is indicated by: the homogeneous orientation of minerals with prizmatic development in the direction of the trend of regional structures and of the extension of the batholiths themselves; the unusual structure in regard to the orthoclase and plagioclase, the reverse of that observed in Rapakivi, when there is an absence (or weak development) of granophyre intergrowths and signs which support the reciprocal reaction of mineral phases; the schist texture of hornstone, which develops in contacts of batholiths, as distinguished from the masses of hornstones, which accompany fissure intrustions.

Porphyrite thicknesses (the Devonian and lower Carboniferous of Kazakhstan, the upper paleozoic of the Kuraminsk zone of the western Tyan'-Shan', etc) are peculiar to secondary geosynclines in the effusive phase. The accumulation of porphyrite thicknesses takes place mainly on the sides of anticlinorie and usually precedes the penetration of granite intrustions in time. It is very probable that there is a genetic connection between porphyrite thicknesses and granite batholiths in regard to a common source for their magmatic material.

In eruptive bodies of granitoids which are formed in the development phase of secondary geosynclines the metallic components of magma are not separated from its silicate mass and continues to remain in it in a finely dispersed state. This explains the absence of significant ore deposits directly connected with batholiths. Only at the very end of the phase considered, when the batholiths represent almost completely solidified bodies, in connection with the sharp abatement of regional stresses, which change the ratio of pressures inside the center and in the surrounding environment, does boiling of magma take place, in which great quantities of gaseous products which have been concentrated in the metallic component are separated out. In the period when the magma is boiling, the environment surrounding the batholiths continues to be kept impermeable and only in zones of contacts which have been heated by batholiths and in the apical sectios of the batholiths themselves does there begin to develop decreased condensation. This is due to the irregular decrease of the dimensions of the rocks, which underwent cooling when the periphery crust of the batholiths cooled. When this process occurred in a homogeneous mass of batholiths there appeared a fine cleavage and scaling developed along the surfaces of the contacting geological bodies which differed in lithological composition and in mechanical properties (the contact surfaces of the intrusions with sedimentary rocks, some strata surfaces, surfaces of overthrust, etc). Among large planes of scaling, thinner contraction of rocks took place. This is expressed in microscopic formations: in scaling along the surfaces of mineral fragments and along facets of crystals, in openings of cracks, etc. These zones of decreased condensation of rocks which develop along the boundaries of the heterogeneous environment are at the moment considered the only funnel for the outcropping of magmatic emanations. The close conditions of circulation of the emanations along the thinnest cavities are close in character to capillary seepage, favoring an interaction with the steaming lateral rocks that are represented in the silicate and mineral metasomatose.

Greisens, skarns and secondary quartzite are related to the number of typical mineral formations of the development phase of secondary geosyncline systems. It may be assumed that these three most widely spread and important industrial kinds of metasomatic rocks are genetic analogues, frequently arising simultaneously in the same geological situation and through emanations are clse in composition; they differ only in regard to the character of the rocks that undergo decomposition. Skarns are developed in carboniferous rocks, greisens in acid rocks with high alkaline content, and secondary quartzites in moderately acid rocks relatively poor in alkalines. Therefore, in the paragenetic association of skarns there are almost exclusively calcium minerals, in the paragenetic association of greisens free silicic acid and minerals with a relatively high alkaline content, and in the paragenetic association of secondary quartzites there are minerals rich in alumina. The common origin of skarns, greisens and secondary quartzites is reflected also in the monotupe character of their mineralization represented by deposits of impregnated ores and stockwork bodies with typical association of iron, copper, wolfram, arsenic, molybdenum and tin. Related to this genetic group (but only to the lower temperature phase) are polymetallic beds and metasomatic barytic deposits in carboniferous thicknesses (Kara-Tau).

Metasomatic mineralization reached the greatest dimension in the basin phase of the development of Kazakhstan and western Tyan'-Shan'. Typical of sedimentary mineral resources of secondary geosyncline systems are deposits of coal, oil, various salts, iron and manganese ores.

Metamorphism and Folding.

Deposits of secondary geosyncline systems, as a rule, are distinguished by the complete absence of displaced metamorphism.

Changed rocks are found here in contact with granite intrustions and in zones of large fractures. In the latter, shearing at times reaches great intensity.

Folding of secondary geosyncline systems is characterized by large, long developing forms. On the slanting sides of geosyncline basis are developed gashed anticlines, flexures, monoclines, brachyanticlines, brachysynclines and only in collapsed parts of asymmetrical basis is there detected a more complicated folding close to the linear folds of marginal depressions.

Structural forms of secondary geosyncline systems throughout the whole period of development find direct reflection in the relief through which they influence sediment accumulation.

On the sides of positive structurel units are observed quick facial changes, decreases of thicknesses in separate horizons, and even local stratigraphic and angular non-conformities.

Origin of Secondary Geosyncline Systems.

The development phases of primary geosyncline systems, as has been pointed out, ending with the cessation of folding and sediment accumulation within the troughs and with the appearance of a flat relief. The plain formed on the area of the primary geosyncline system later is the initial surface for a secondary geosyncline system.

The structural development of secondary geosyncline systems is expressed in forming basins, geoanticline crests, marginal depressions and various finer tectonic units that are irreversible. The development of the latter is largely predetermined by a structural plan received from the preceding phase.

Some tectonic elements of secondary geosyncline systems are inherited, others are formed anew. The Mugodzharsk geoanticlines in the Urals, the Ulutausk, Kokchetausk and others in Kacakhstan, inherit the platform ridges of earlier phases of development. In the Zerabshano-Altay mountain r egion, in Chingiz and in Tarbagatau, the geoanticline crests on the other hand, are newly formed elements, presenting uplifts of earlier locked geosyncline troughs.

Large geosyncline basins at times are distributed as central parts in intergeosyncline platform fragments with slight sediment deposits of the primary phase. The following can be cited as examples of such geosyncline basins: the northeastern Pribalkhashe in the period from the Caradoc to the middle Carboniferous, the Dzhezkazgansk and the Tenizsk depression in the period from the middle Devonian to the middle Carboniferous, and many others.

In secondary geosyncline systems, those parts of the moving belt which during the phase of primary geosyncline development remained in general submersion, undergo lowering. In geosyncline basins superimposed on the intervening platform projections inside the primary systems and in advanced depressions distributed on the edges of large platform regions, an older base is lowered to a depth of 5 - 10 kilometers. The general area of the regions of the deeply lowered platform base increases still more by the end of the secondary geosyncline system phase.

The process of disintegration and immersion of the fragments of the pre-Cambrian platform socle, which embraces newer and newer regions, is the leading motif in the development of the structure of the earth's crust during the geosyncline stage.

The decisive role in this process belongs to lowerings, which are not compensated for by emanations. The filling of depressions with sediments goes on primarily not by erosion and redepositing the rocks of the platform foundation projections in the geosyncline system, but mainly by accumulating material of magmatic, partly organogenous and chemical origin, as well as their redeposited products. The material of geosyncline systems arise, as a result of redistributing substances on the surface of the earth and mainly by adding it from the subcrust.

Residual Geosyncline Systems

Residual geosyncline systems in their development show signs of a final extinguishing of a geosyncline system. In phases of residual geosyncline systems, a change-over of the tectonic plan does not take place; large new tectonic elements do not appear, but structure formation goes on as in the previous plan in a very weakened form.

In the course of this third phase the geosyncline region reaches a state of stability which closely resembles the platform. Among other things, this state has served as a means of separating similar regions into categories of young platforms.

Residual geosynclines are vast flat basins and depressions, morphologically close to the syneclase of platforms. In paleogeographic terms they have the character of a large plain, the framework of which are low hilly areas, residual geoanticlines, regions of final denudation.

Formations of shallow epicontinental sea deposits and especially lagoon formations and continental sediments are characteristic of residual geosyncline systems. Shell limestones, marls, dolomites, red-colored argillites, sandstones, and coal-bearing deposits develop in them.

A typical example of residual geosyncline systems is central Kazakhstan in the lower Paleozoic (middle Carboniferous - Permian) and Tyan'-Shan' at the end of the Permian and in the lower Mesozoic.

The Dzhezkazgansk, Tenizsk and Zaysansk depressions of upper Paleozoic time, the Iliysk, Dzhungarsk and Fergansk depressions at the end of the Permian and in the Mesozoic give an idea of the morphological character and the types of sediments of the tectonic regions being considered.

Magmatic appearances in residual geosyncline systems are represented by cleavage intrusions, laccolites of various forms and dikes, which develop in residual geoanticlines and along fractures. The absence of regional stress in the earth's crust in this phase favors differentiation of magmatic centers which, with each stage of development of cleavage structures, send out newer and newer products. In a number of residual geosynclines, where formation of cleavage structures was long and multiphase, among cleavage intrusions and dikes, several systems of different ages can be separated out -- up to 10 -- by which the order of magmatic evolution can be traced.

In intrusive series the earliest penetrations, as a rule, are represented by members of the alkaline order: alaskites, alkaline granites and syenites (frequently nephelin), then come granite-porphyrites and quartz porphyrites, and still later -- porphyrites and microdiorites, and last of all diabase and lamprophyres.

In forming cleavage intrusions, magma comes from the depths in a fused form. Assimilation thereby does not develop; on the contrary, signs of mechanical action of magma on lateral rocks are detected. The source of magma for fissure intrusions, probably are deep-lying batholitic bodies, which finally did not transform into a solid state.

In contrast to platform intrustions, fissure intrusions of residual geosynclines do not form extreme laminated rocks of monomineral composition, since they lack clearly expressed flow structures and never take the forms of sheet-like deposits. A characteristic feature of the rocks of fissure intrustions is a strong development of autometamorphism which causes albitization of the orthoclase in acid varieties, muscovitization of mica, and a deposit of fluorite or calcite, and in basic varieties epidotization and carbonization.

Extreme members in residual geosynclines have limited development. When there is an especially intensive and long volcanic activity in regions of the development of residual geosynclines, there are thicknesses of motley petrographic composition, in general acids which manifest approximately that evolution of magmatic fusion as in subsurface forms: orthophyres -- quartz porphyres --

porphyrites and basalts.

The phases of residual geosynclines which are characterized by development of fissure systems have vein mineralization. Mineral bodies of this type are formed in open cavities by deposits of mineral substance on walls. In creating a lode, two parallel flowing processes take part: cleavage and ore mineralization, which disintegrates with a series of detonations, to each of which correspond bodies of several different morphology (sometimes even direction) and with special ore composition. Characteristic metals of mineralization vein type in early detonations are tin, molybdenum, wolfram, gold and arsenic; in middle detonations copper, zinc, lead and silver; with late detonations, mercury, antimony, arsenic and gold.

Ore bodies of the vein type, like the fissure intrustions preceding them, are usually concentrated in residual geoanticlines which inherit geoanticlines of the preceding phase of development.

Subsequent development of fissures from the subsurface to the surface and from the center of the controlling structural unit to its periphery explains the zonality in vertical and horizontal directions which is characteristic of vein deposits.

Typical mineral resources associated with sedimentary rocks are: oil, coal, salts, copper, sandstone. Deposits of residual geosynclines in considerable areas are not destroyed; they lie horizontally or slightly slanted. Their characteristics are single dome-shaped folds, flexures, monoclines, folds, gashed anticlines, which are usually distributed among areas with horizontal strata. The structural forms enumerated develop lengthwise and are reflected in the relief and in the sediment.

The submersion of the platform foundation continues into the development phase of residual geosyncline systems.

CONCLUSION

The characteristics of the development of geosyncline systems which have just been propounded have been summarized in very schematic form in a chart. Of the different phenomena set forth, we have attempted to note only some of the most typical signs, which in en toto give a sufficiently clear presentation of the phases of development of geosynclines. Therefore, it is necessary to again emphasize that using one group of indicators, be it metallogany, magmatism, folding, metamorphism or formations of rocks, makes it difficult to show differences in phases of development at the present state of our knowledge, and the results are highly disputable. Therefore, in separating phases of development of geosyncline systems, it is necessary to use not a single indicator, but the whole complex of the most typical indicators.

Our conclusions for the most part differ from prevailing viewpoints, but they coincide with some of the latest statements that the transformation of substances in the subcrust zone, accompanied by an irregular abrupt decrease of its size, cause a corresponding reaction of the crust. As we have seen the development in the platform-geosyncline stage shows the great importance of lowerings (to which uplifts are subordinated) which embrace, in the course of time, newer and newer areas. The lowerings develop in belts of subsurface fractures which form on the Archean-Proterozoic cover (platform) geosyncline systems, filled up by thicknesses of new sediments. The role of subsurface fractures in forming structures is exceptionally great and continues to increase as the crust expands and strengthens mechanically. In upper Proterozoic, Paleozoic, Mesozoic and Cenozoic orogenic epochs, fractures become the most important structural factor, which determines the movement and distribution of matmatic masses.

Primary geosyncline systems arise each time in new places, revealing in this way the tendency to envelop successively a considerable part of the earth's surface. In the final account, there appears another cover of the earth's crust which is the produce of the geosyncline-platform stage of development, differing from the pre-geosyncline crystalline Archeo-lower-Proteroic cover, the formation of which had its own specific peculiarities.

Coming to these conclusions we naturally cannot accept the concepts of universal cycle operations in the history of the earth, of the inverse and reverse of vertical movements, of mutual compensation of uplifts and lowerings, etc. These ideas, based on an incorrect understanding of vertical movements, do not explain the natural phenomena and are foreign to the principle of development.

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CHARACTERISTICS OF THE PHASES OF GEOSYNCLINE DEVELOPMENT

Indicators	Primary geosyncline systems	Secondary geosyncline systems	Residual geosyncline systems
[1]	[2]	[3]	[4]
General morphology and origin	Narrow linear troughs with intervening platform projections, arising in belts of subsurface fractures	Broad geosyncline basins, distributed on intervening platform projections; advanced depressions stretched out along the edges of a platform; geoanticline crests, arising out of folded complexes of geosyncline troughs. Their tectonic elements at times inherited from primary geosyncline systems	Vast flat hollows and uplifts, much like sineclase and anticlase of platforms which inherit the most important tectonic elements of secondary geosyncline systems

[1]	[2]	[3]	[4]
Sedimentary formations	Characteristic is the development of exceptional sea deposits. Widespread formations of: graywacke-schist, jasper, upper Proterozoic pelitomorphic limestones and flysch	Alternation of sea and continental-lagoon deposits. Typical formations are: organogenous-brecciated limestones, red-colored lagoon, coal-bearing and molasse	Predominance of continental-lagoon deposits. Developed formations: coal-bearing, shell limestones, dolomites motley-colored argillites and sandstones
Intrusive formations	Bodies of dynamically metamorphic basic and ultrabasic rocks (ophiolites) forming belts along subsurface fractures	Batholitic bodies of eruptive granitoids, distributed chiefly in geoanticlines	Cleavage intrusions and dikes of diverse composition
Extrusive formations	Spilite-ceratophyre formations	Porphyrite formations	Ground emanations of motley composition but chiefly acids

[1]	[2]	[3]	[4]
Metallogeny	Formation of magmatogenous beds: deposits of pyrites, copper-nickel sulfides, chromites, titanomagnetites and platinum bearing horizons	Formation of metasomatic beds: orebearing skarns, secondary quartzites and greisens with associations of iron, copper, wolfram, molybdenum, arsenic and tin	Formations of vein mineralization with diversity of types
Folding	Strongly compressed, usually shallow equal anticlines and synclines with plunging hintes, short periods of development	Brachyanticlines and brachsynclines, large open and linear folds with horizontal hinges, long development, reflected in the relief and sediment phases	Flexutes, monoclines, gashed anticlines and domes with long multiphase development
Metamorphism	Strong displaced metamorphism more or less homogeneous along the whole geosyncline system	Significant contactual metamorphism with granite intrusions	Absent or significance destroyed

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